Related Pending Application
Related Case Serial No: 09/944,075
Related Case Filing Date: 09-04-01

WHAT IS CLAIMED IS:

1. A magnetoresistance effect element comprising:

two ferromagnetic layers, one of the two ferromagnetic layers being a magnetization fixed layer having a magnetization direction substantially fixed to one direction, and the other ferromagnetic layer being a magnetization free layer having a magnetization direction varying in response to an external magnetic field;

a non-magnetic layer provided between the ferromagnetic layers; and

a layer containing an oxide or nitride as a principal component containing a magnetic transition metal element which does not bond to oxygen and nitrogen and which is at least one of Co, Fe and Ni,

the magnetoresistance effect element having a resistance varying in response to a relative angle between the magnetization direction of the magnetization fixed layer and the magnetization direction of the magnetization free layer.

2. A magnetoresistance effect element as set forth in claim 1, wherein the layer containing the oxide or nitride as the principal component contains a magnetic transition metal element of Co which does not bond to oxygen and nitrogen.

3. A magnetoresistance effect element as set forth in claim 1, wherein a thickness of the layer containing the oxide or nitride as the principal component is in the range of from 1 nm to 3 nm.

4. A magnetoresistance effect element as set forth in claim 1, wherein the layer containing the oxide or nitride as the principal component contains an oxide or nitride of any one of Fe, Co, Ni, Mn, Cr, V, Ti, Zr, Mo, Hf, Ta, W and Al.

5. A magnetoresistance effect element as set forth in claim 1, wherein the magnetization fixed layer comprises a plurality of stacked layers, and the layer containing the oxide or nitride as the principal component is provided between layers

constituting the magnetization fixed layer.

6. A magnetoresistance effect element as set forth in claim 5, wherein a thickness of the layer constituting the magnetization fixed layer between the non-magnetic layer and the layer containing the oxide or nitride as the principal component is in the range of from 1 nm to 3 nm.

7. A magnetoresistance effect element as set forth in claim 1, wherein the magnetization fixed layer comprises: a layer having a magnetization direction substantially fixed to one direction; a second non-magnetic layer; and a third ferromagnetic layer antiferromagnetically bonding to the layer having the magnetization direction substantially fixed to one direction, via the second non-magnetic layer.

8. A magnetoresistance effect element as set forth in claim 1, wherein the layer having the oxide or nitride as the principal component contacts an opposite surface of the magnetization free layer to the non-magnetic layer via the second non-magnetic layer.

9. A magnetoresistance effect element as set forth in claim 8, wherein a total thickness of the magnetization free layer and the second non-magnetic layer is in the range of from 2 nm to 4 nm.

10. A magnetoresistance effect element as set forth in claim 1, wherein an atomic composition of at least one of argon, xenon, helium, krypton and neon contained in the layer containing the oxide or nitride as the principal component is twice or more as much as the atomic composition of that in the layer which contacts the layer containing the oxide or nitride as the principal component.

11. A magnetoresistance effect element comprising:

a magnetization fixed layer having a ferromagnetic layer having a magnetization direction substantially fixed to one

direction;

a magnetization free layer having a ferromagnetic layer having a magnetization direction varying in response to an external magnetic field;

a non-magnetic intermediate layer provided between the magnetization fixed layer and the magnetization free layer;

a high conductive layer having a higher conductivity than those of the magnetization fixed layer and the magnetization free layer, being stacked on one side of the magnetization free layer remoter from the non-magnetic intermediate layer; and

a non-magnetic crystalline layer provided on one side of the high conductive layer remoter from the magnetization free layer, and containing a compound of an element, which is different from the principal element constituting the high conductive layer, as a principal component, the non-magnetic crystalline layer having a substantially non-magnetism and being substantially crystalline.

12. A magnetoresistance effect element as set forth in claim 11, wherein the non-magnetic crystalline layer contains at least one of oxides of B, Si, Ge, W, Nb, Mo, P, V, Sb, Zr, Ti, Zn, Pb, Cr, Sn, Ga, Fe, Co and rare earth metals.

13. A magnetoresistance effect element as set forth in claim 11, wherein a thickness of the non-magnetic crystalline layer is in the range of from 0.5 nm to 5 nm.

14. A magnetoresistance effect element as set forth in claim 11, wherein a thickness of the high conductive layer is in the range of from 0.5 nm to 3 nm.

15. A magnetoresistance effect element comprising:

a magnetization fixed layer having a ferromagnetic layer having a magnetization direction substantially fixed to one direction;

a magnetization free layer having a ferromagnetic layer having a magnetization direction varying in response to an

external magnetic field;

a non-magnetic intermediate layer provided between the magnetization fixed layer and the magnetization free layer;

a high conductive layer having a higher conductivity than those of the magnetization fixed layer and the magnetization free layer, being stacked on one side of the magnetization free layer remoter from the non-magnetic intermediate layer;

a first compound layer provided on one side of the high conductive layer remoter from the magnetization free layer, and containing a oxide of an element, which is different from the principal element constituting the high conductive layer, as a principal component; and

a second compound layer provided on one side of the first compound layer remoter from the high conductive layer.

16. A magnetoresistance effect element as set forth in claim 15, wherein the first compound layer contains an oxide of a first element selected from a ranking of elements consisting of B, Si, Ge, Ta, W, Nb, Al, Mo, P, V, As, Sb, Zr, Ti, Zn, Pb, Th, Be, Cd, Sc, La, Y, Pr, Cr, Sn, Ga, Cu, In, Rh, Pd, Mg, Li, Ba, Ca, Sr, Mn, Fe, Co, Ni, and Rb, as a principal component and

the second compound layer contains an oxide of an element of the ranking of elements arranged after the first element, as a principal component.

17. A magnetoresistance effect element as set forth in claim 15, wherein a total thickness of the first compound layer and the second compound layer is in the range of from 0.5 nm to 5 nm.

18. A magnetoresistance effect element as set forth in claim 11, wherein a thickness of the high conductive layer is in the range of from 0.5 nm to 3 nm.

19. A magnetoresistance effect element comprising:

a magnetization fixed layer having a ferromagnetic layer having a magnetization direction substantially fixed to one

direction;

a magnetization free layer having a ferromagnetic layer having a magnetization direction varying in response to an external magnetic field;

a non-magnetic intermediate layer provided between the magnetization fixed layer and the magnetization free layer;

a high conductive layer having a higher conductivity than those of the magnetization fixed layer and the magnetization free layer, the high conductive layer being stacked on one side of the magnetization free layer remoter from the non-magnetic intermediate layer, and

a layer containing an oxide of an element different from the principal element constituting the high conductive layer, as a principal component, and being formed by the irradiation with an ionized gas and stacked on the high conductive layer.

20. A magnetoresistance effect element comprising:

a magnetization fixed layer having a ferromagnetic layer having a magnetization direction substantially fixed to one direction;

a magnetization free layer having a ferromagnetic layer having a magnetization direction varying in response to an external magnetic field;

a non-magnetic intermediate layer provided between the magnetization fixed layer and the magnetization free layer;

a high conductive layer having a higher conductivity than those of the magnetization fixed layer and the magnetization free layer, the high conductive layer being stacked on one side of the magnetization free layer remoter from the non-magnetic intermediate layer; and

a layer containing an oxide of an element different from the principal element constituting the high conductive layer, as a principal component, and being formed by the irradiation with a plasma gas and stacked on the high conductive layer.

ABSTRACT OF THE DISCLOSURE

There are provided a magnetoresistance effect element, a magnetic head, a magnetic head assembly and a magnetic recording system, which have high sensitivity and high reliability. The magnetoresistance effect element has two ferromagnetic layers, a non-magnetic layer provided between the ferromagnetic layers, and a layer containing an oxide or nitride as a principal component, wherein the layer containing the oxide or nitride as the principal component contains a magnetic transition metal element which does not bond to oxygen and nitrogen and which is at least one of Co, Fe and Ni.

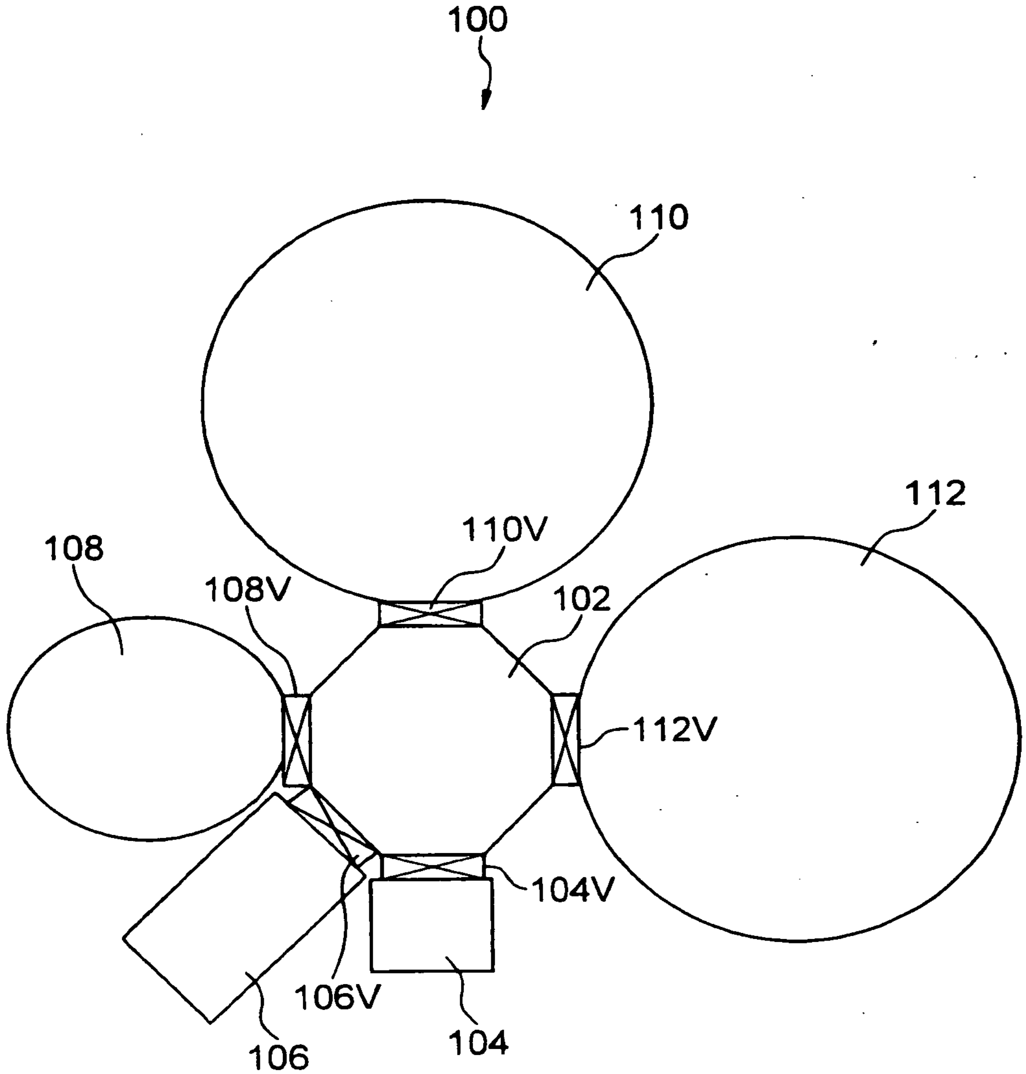


FIG. 1

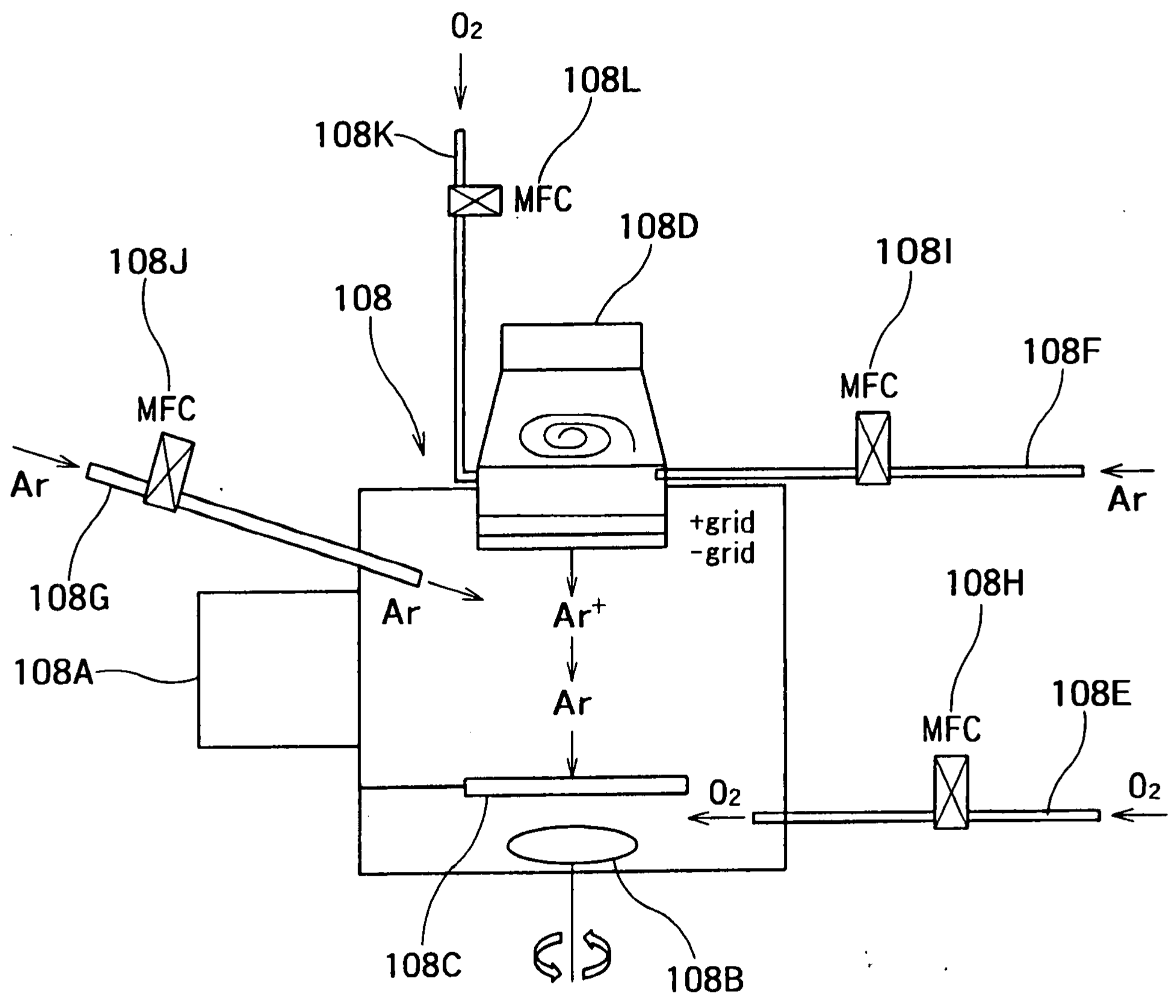

O_2
108L
108K
MFC
108D
108J
108
108I
108F
MFC
MFC
Ar
Ar
+grid
-grid
108G
Ar
Ar^+
108H
108A
Ar
108E
MFC
O_2
O_2
108C
108B

FIG. 2

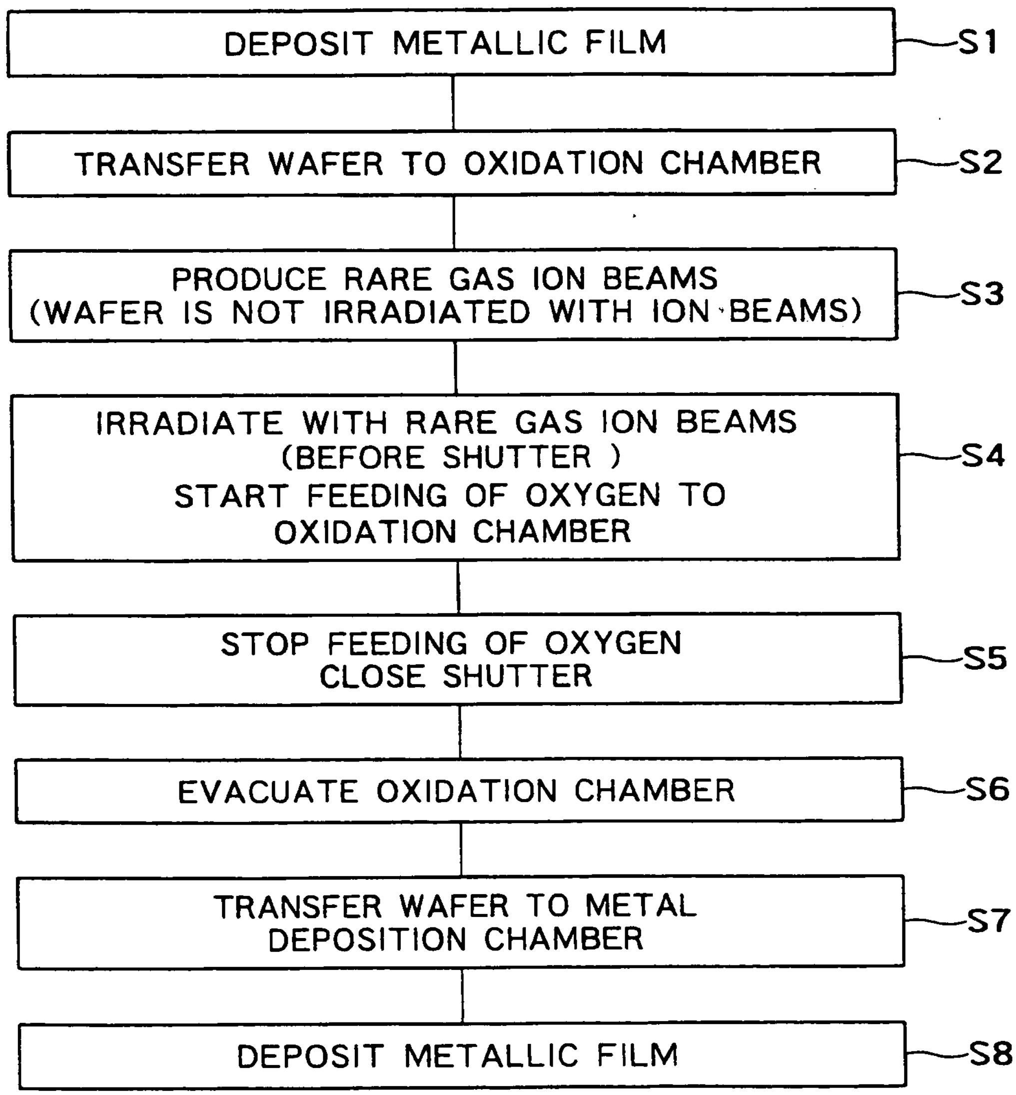

DEPOSIT METALLIC FILM
S1
TRANSFER WAFER TO OXIDATION CHAMBER
S2
PRODUCE RARE GAS ION BEAMS
(WAFER IS NOT IRRADIATED WITH ION BEAMS)
S3
IRRADIATE WITH RARE GAS ION BEAMS
(BEFORE SHUTTER)
START FEEDING OF OXYGEN TO
OXIDATION CHAMBER
S4
STOP FEEDING OF OXYGEN
CLOSE SHUTTER
S5
EVACUATE OXIDATION CHAMBER
S6
TRANSFER WAFER TO METAL
DEPOSITION CHAMBER
S7
DEPOSIT METALLIC FILM
S8

FIG. 3

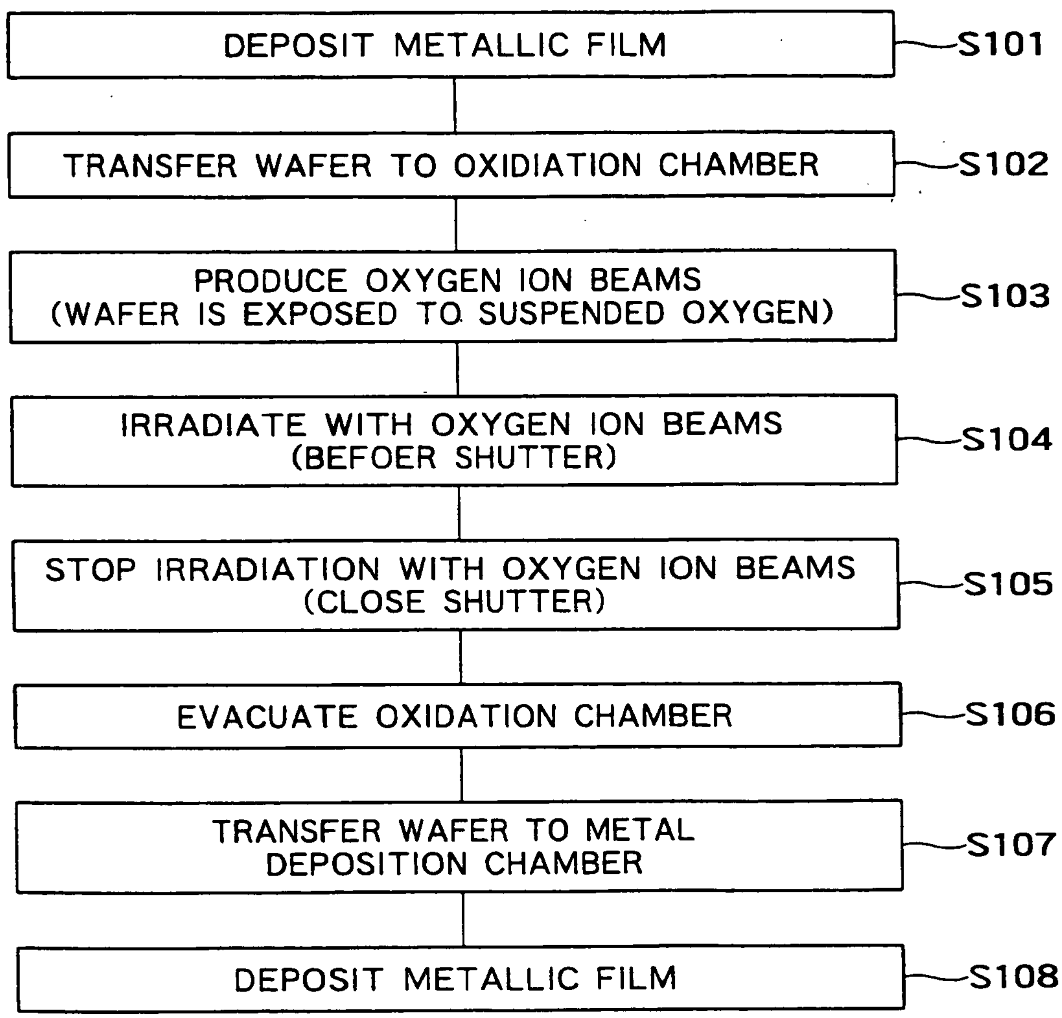

DEPOSIT METALLIC FILM
S101
TRANSFER WAFER TO OXIDIATION CHAMBER
S102
PRODUCE OXYGEN ION BEAMS
(WAFER IS EXPOSED TO SUSPENDED OXYGEN)
S103
IRRADIATE WITH OXYGEN ION BEAMS
(BEFOER SHUTTER)
S104
STOP IRRADIATION WITH OXYGEN ION BEAMS
(CLOSE SHUTTER)
S105
EVACUATE OXIDATION CHAMBER
S106
TRANSFER WAFER TO METAL
DEPOSITION CHAMBER
S107
DEPOSIT METALLIC FILM
S108

FIG. 4

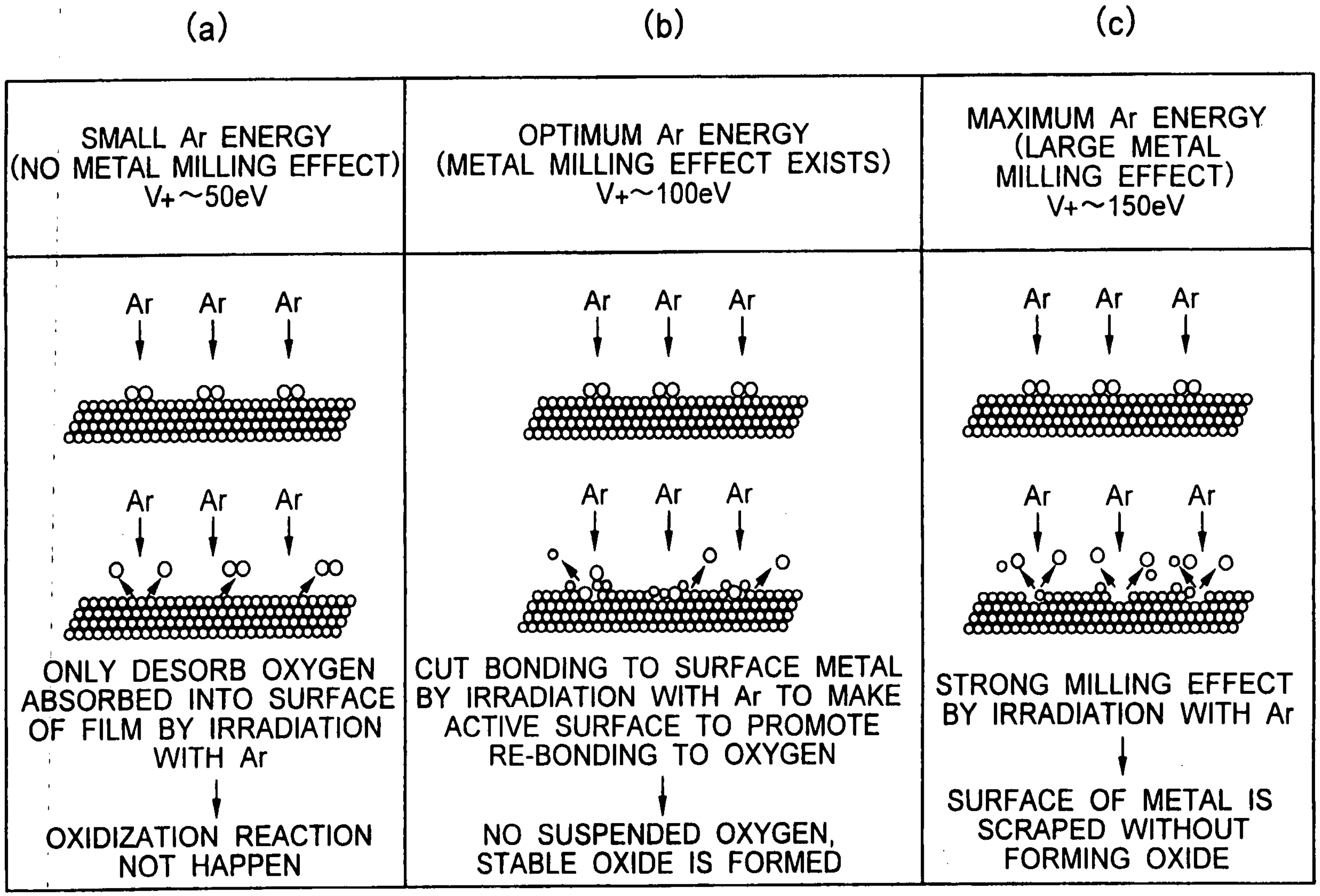

(a)
(b)
(c)
SMALL Ar ENERGY (NO METAL MILLING EFFECT) V+~50eV
OPTIMUM Ar ENERGY (METAL MILLING EFFECT EXISTS) V+~100eV
MAXIMUM Ar ENERGY (LARGE METAL MILLING EFFECT) V+~150eV
Ar
ONLY DESORB OXYGEN ABSORBED INTO SURFACE OF FILM BY IRRADIATION WITH Ar
OXIDIZATION REACTION NOT HAPPEN
CUT BONDING TO SURFACE METAL BY IRRADIATION WITH Ar TO MAKE ACTIVE SURFACE TO PROMOTE RE-BONDING TO OXYGEN
NO SUSPENDED OXYGEN, STABLE OXIDE IS FORMED
STRONG MILLING EFFECT BY IRRADIATION WITH Ar
SURFACE OF METAL IS SCRAPED WITHOUT FORMING OXIDE

FIG. 5

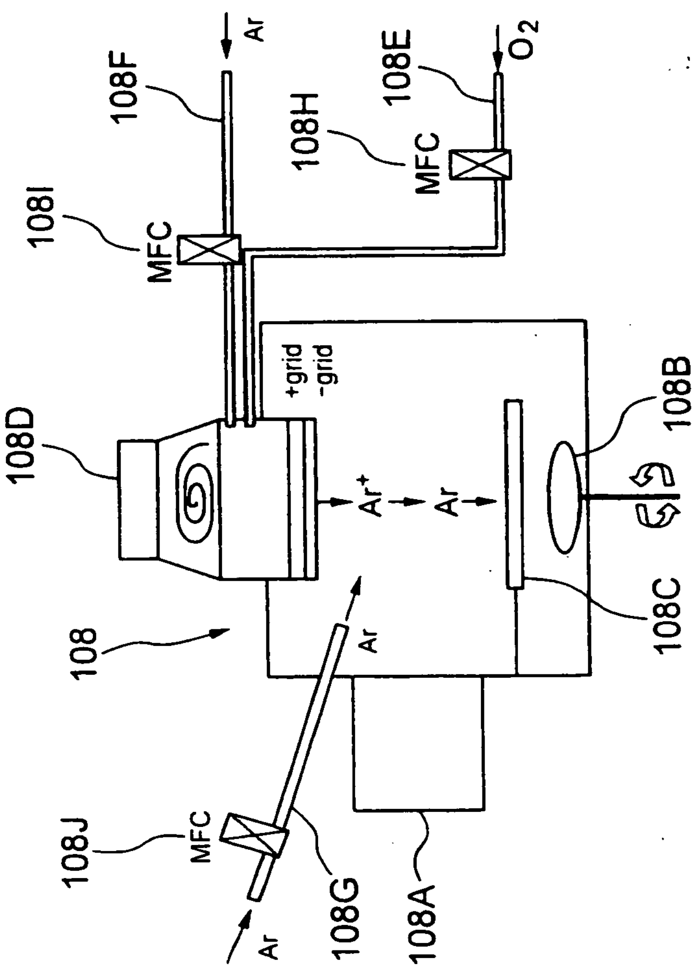

Ar
108F
108E
O_2
108H
MFC
108I
MFC
+grid
-grid
108D
Ar^+
Ar
108B
108C
108
Ar
108J
MFC
108G
Ar
108A

FIG. 6

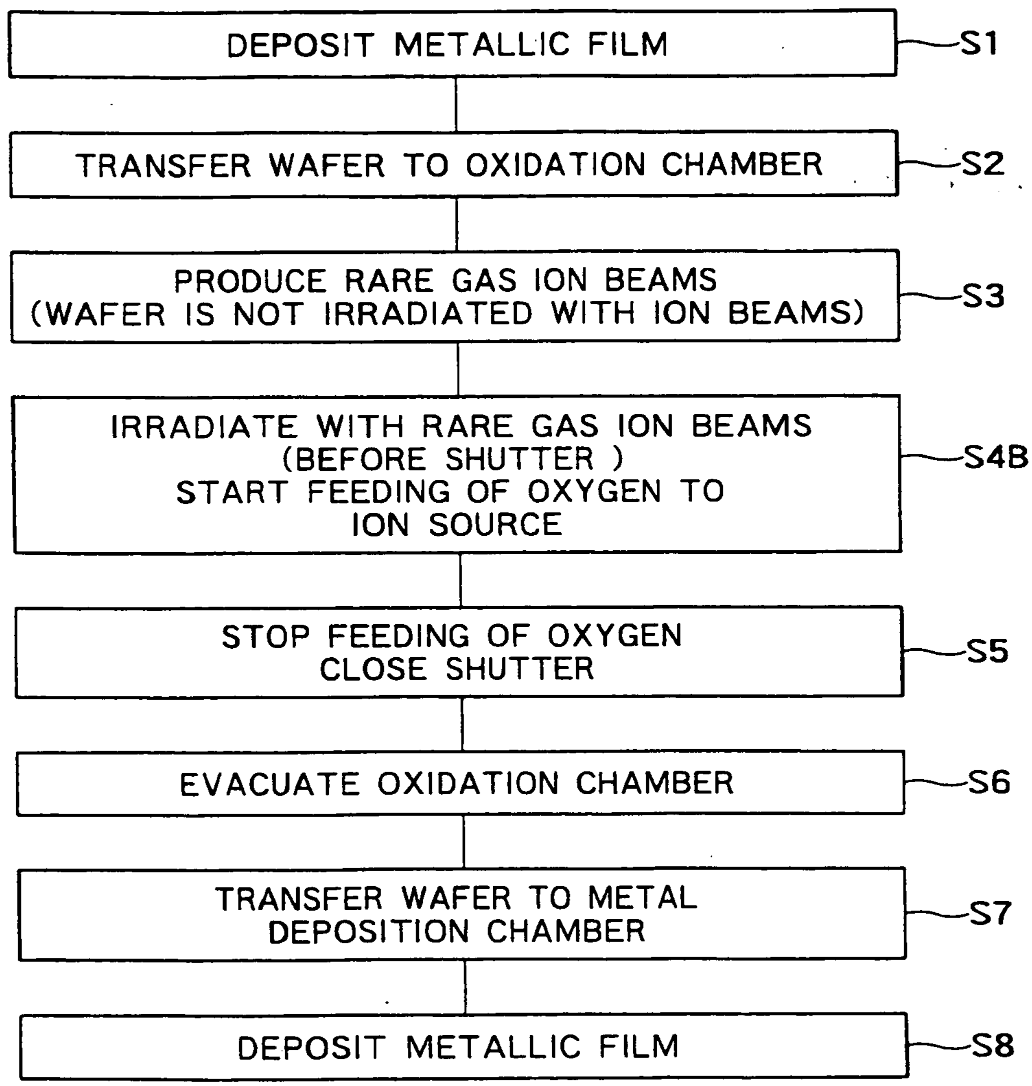

DEPOSIT METALLIC FILM
S1
TRANSFER WAFER TO OXIDATION CHAMBER
S2
PRODUCE RARE GAS ION BEAMS (WAFER IS NOT IRRADIATED WITH ION BEAMS)
S3
IRRADIATE WITH RARE GAS ION BEAMS (BEFORE SHUTTER) START FEEDING OF OXYGEN TO ION SOURCE
S4B
STOP FEEDING OF OXYGEN CLOSE SHUTTER
S5
EVACUATE OXIDATION CHAMBER
S6
TRANSFER WAFER TO METAL DEPOSITION CHAMBER
S7
DEPOSIT METALLIC FILM
S8

FIG. 7

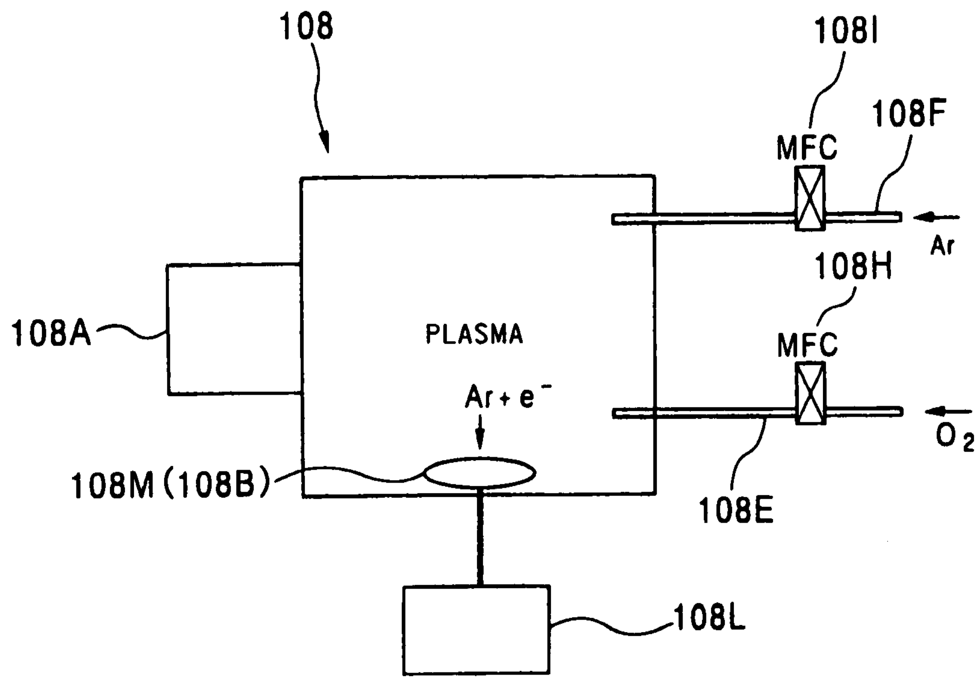

108
108I
MFC
108F
Ar
108H
MFC
O_2
108A
PLASMA
Ar + e⁻
108M (108B)
108E
108L

FIG. 8

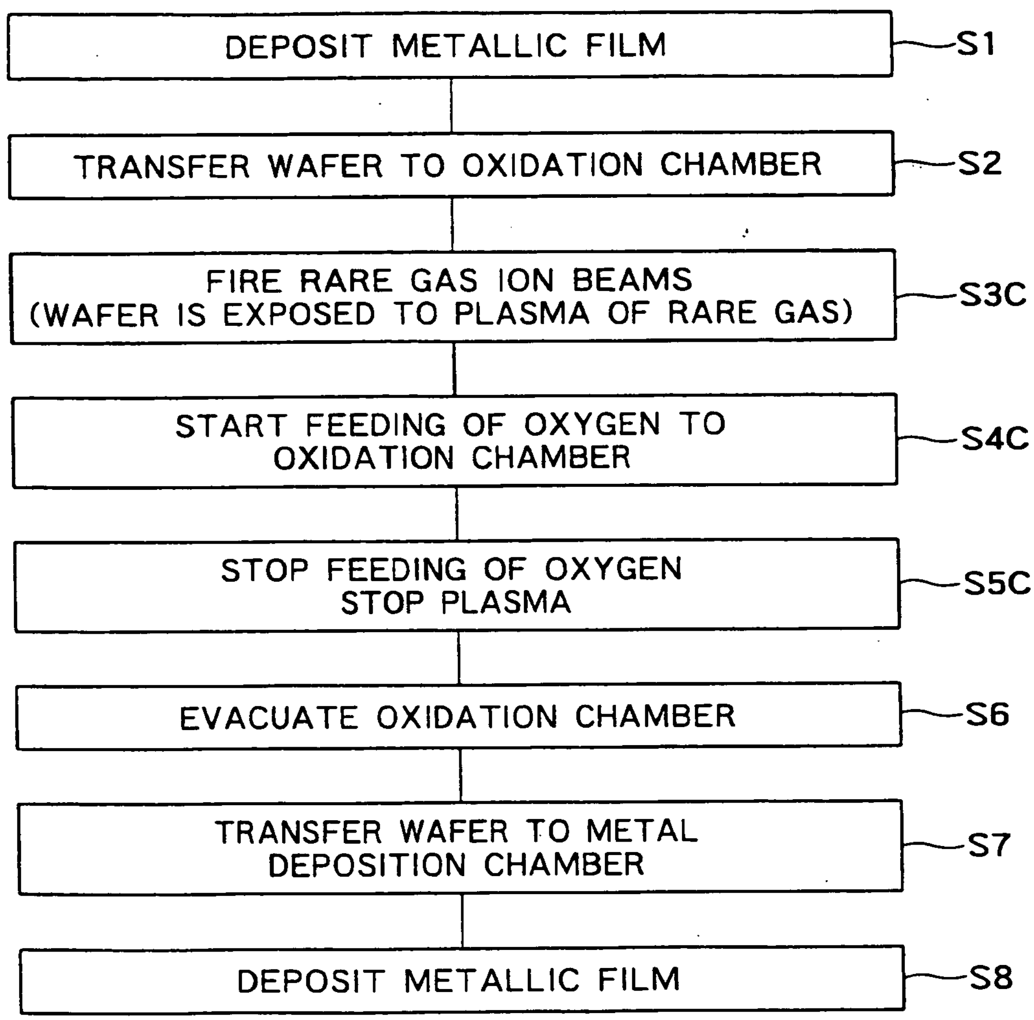

DEPOSIT METALLIC FILM
S1
TRANSFER WAFER TO OXIDATION CHAMBER
S2
FIRE RARE GAS ION BEAMS
(WAFER IS EXPOSED TO PLASMA OF RARE GAS)
S3C
START FEEDING OF OXYGEN TO
OXIDATION CHAMBER
S4C
STOP FEEDING OF OXYGEN
STOP PLASMA
S5C
EVACUATE OXIDATION CHAMBER
S6
TRANSFER WAFER TO METAL
DEPOSITION CHAMBER
S7
DEPOSIT METALLIC FILM
S8

FIG. 9

FIG. 10

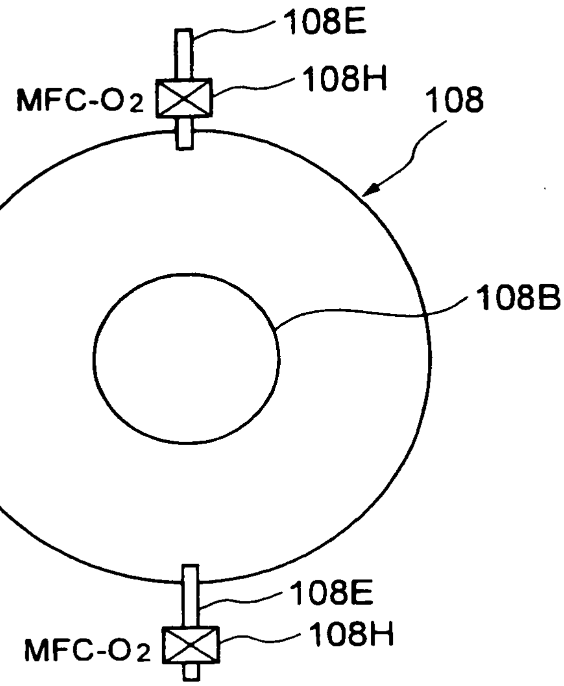
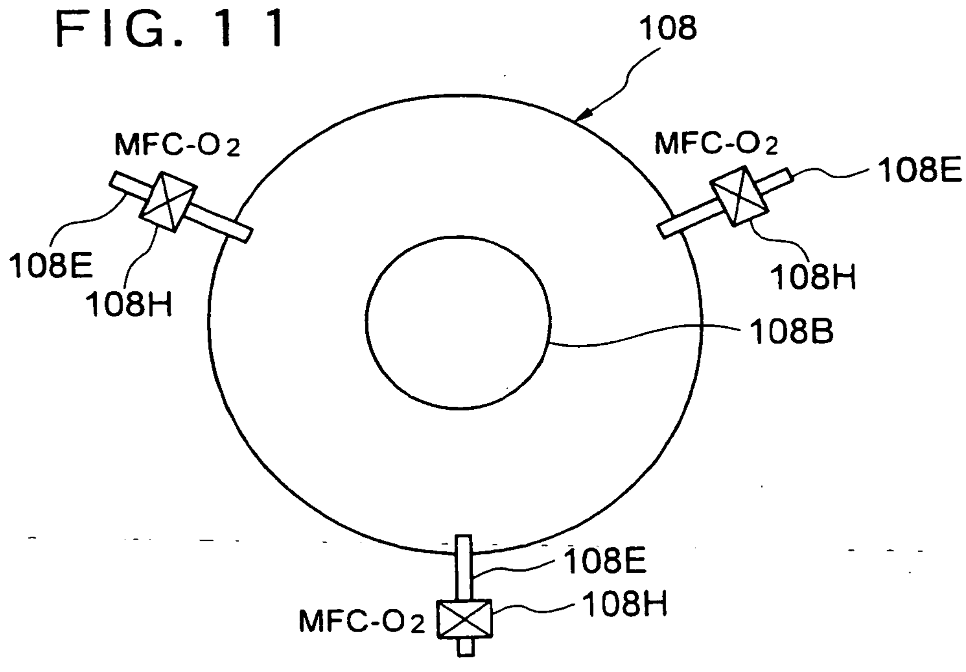

108E
MFC-O2
108H
108
108B
108E
MFC-O2
108H

FIG. 11


108
MFC-O2
MFC-O2
108E
108E
108H
108H
108B
108E
MFC-O2
108H

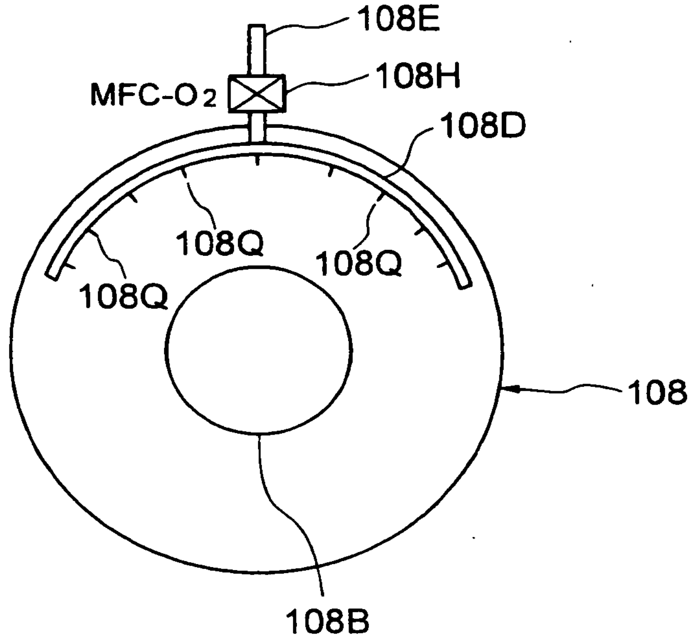
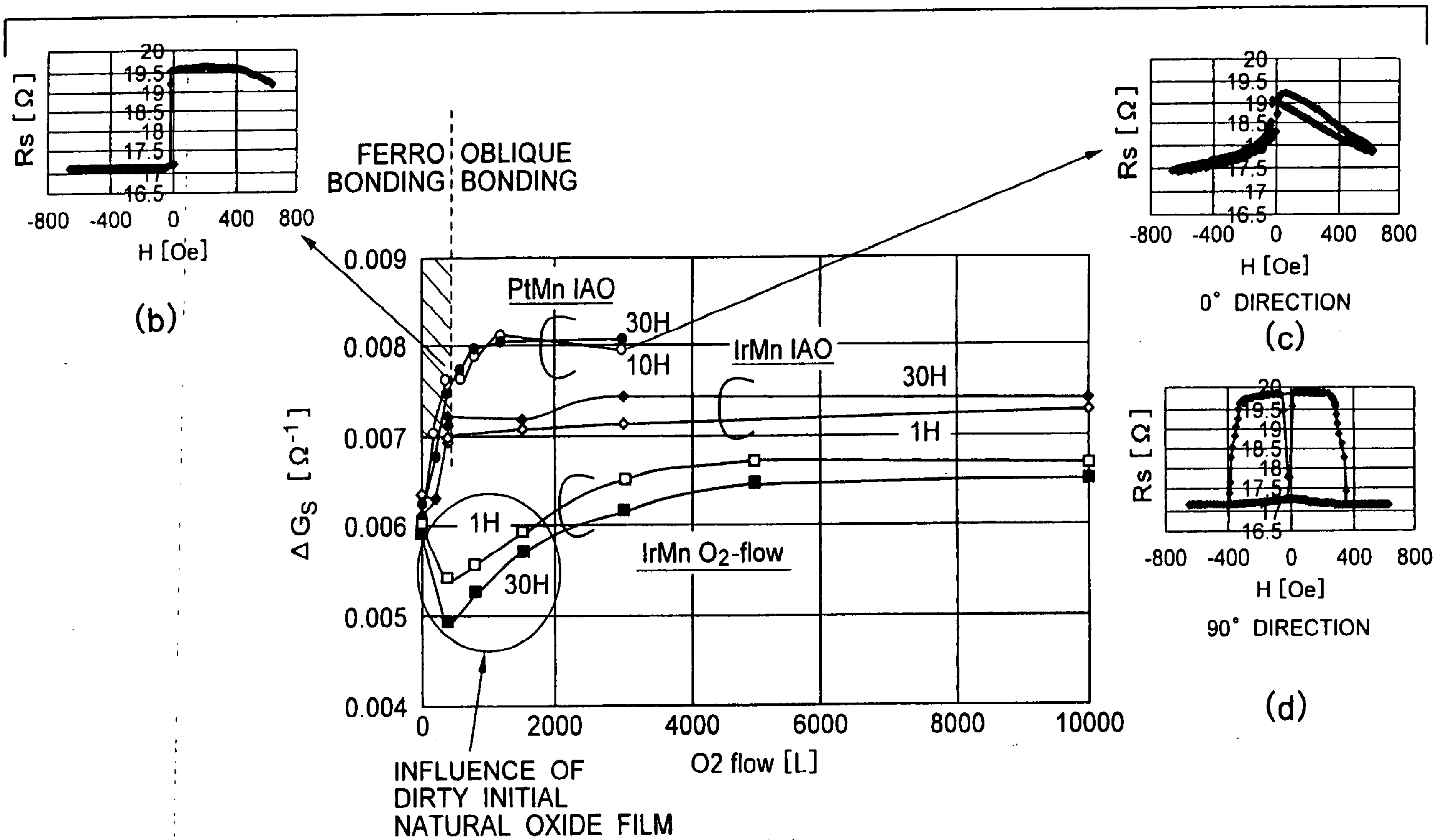


FIG. 12



Rs [Ω]
20
19.5
19
18.5
18
17.5
17
16.5
-800
-400
0
400
800
H [Oe]
(b)
FERRO BONDING
OBLIQUE BONDING
PtMn IAO
30H
10H
IrMn IAO
30H
1H
IrMn O2-flow
1H
30H
ΔGs [Ω-1]
0.009
0.008
0.007
0.006
0.005
0.004
0
2000
4000
6000
8000
10000
O2 flow [L]
INFLUENCE OF DIRTY INITIAL NATURAL OXIDE FILM
(a)
0° DIRECTION
(c)
90° DIRECTION
(d)

FIG. 13

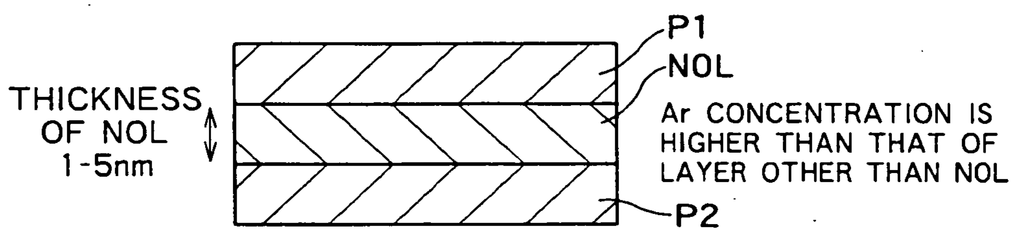

P1
NOL
THICKNESS OF NOL 1-5nm
Ar CONCENTRATION IS HIGHER THAN THAT OF LAYER OTHER THAN NOL
P2

FIG. 14

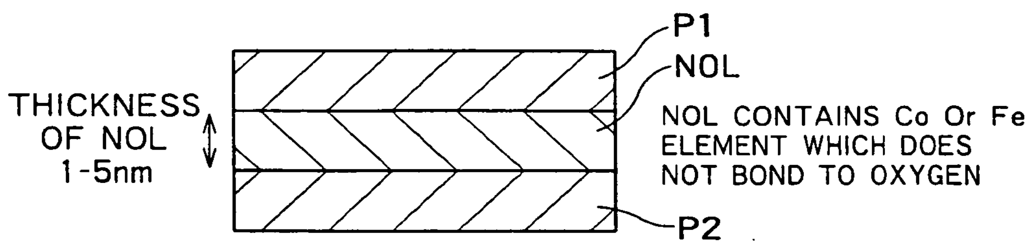

P1
NOL
THICKNESS OF NOL 1-5nm
NOL CONTAINS Co Or Fe ELEMENT WHICH DOES NOT BOND TO OXYGEN
P2

FIG. 15

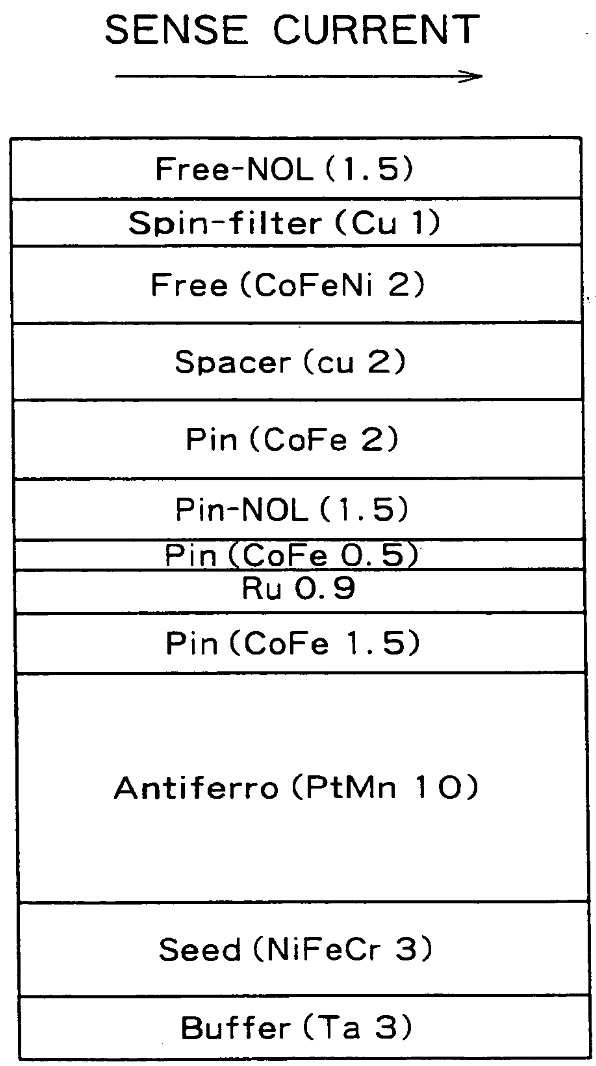

SENSE CURRENT
Free-NOL (1.5)
Spin-filter (Cu 1)
Free (CoFeNi 2)
Spacer (cu 2)
Pin (CoFe 2)
Pin-NOL (1.5)
Pin (CoFe 0.5)
Ru 0.9
Pin (CoFe 1.5)
Antiferro (PtMn 10)
Seed (NiFeCr 3)
Buffer (Ta 3)

FIG. 16

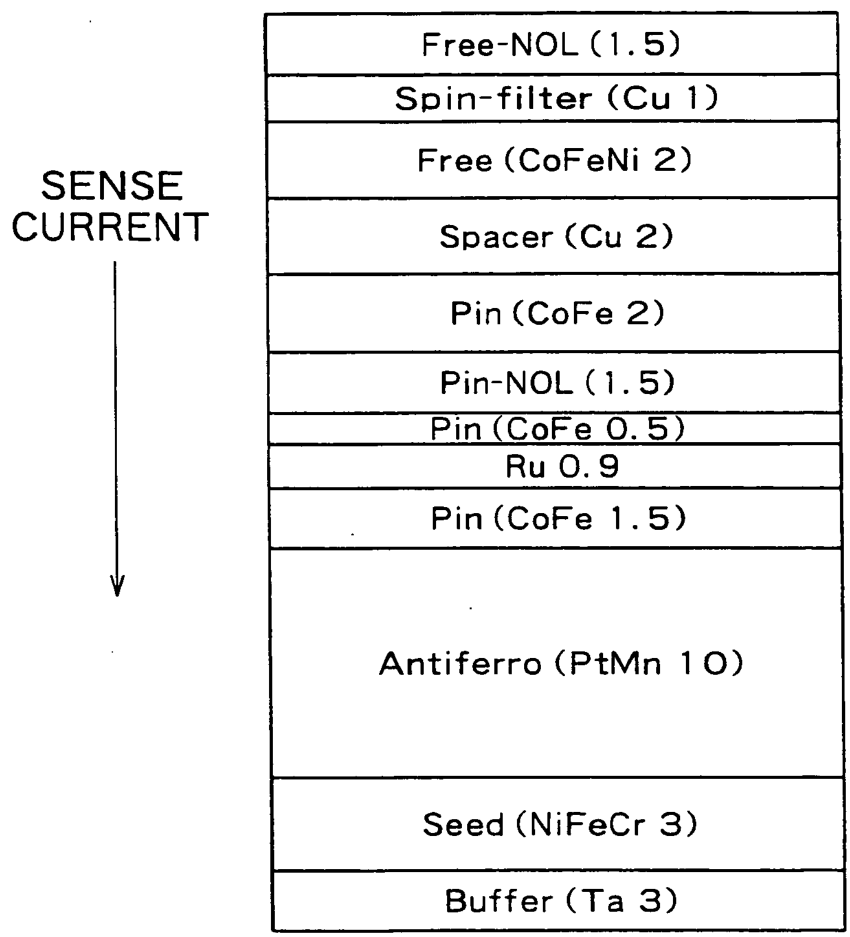

Free-NOL (1.5)
Spin-filter (Cu 1)
Free (CoFeNi 2)
Spacer (Cu 2)
Pin (CoFe 2)
Pin-NOL (1.5)
Pin (CoFe 0.5)
Ru 0.9
Pin (CoFe 1.5)
Antiferro (PtMn 10)
Seed (NiFeCr 3)
Buffer (Ta 3)
SENSE CURRENT

FIG. 17

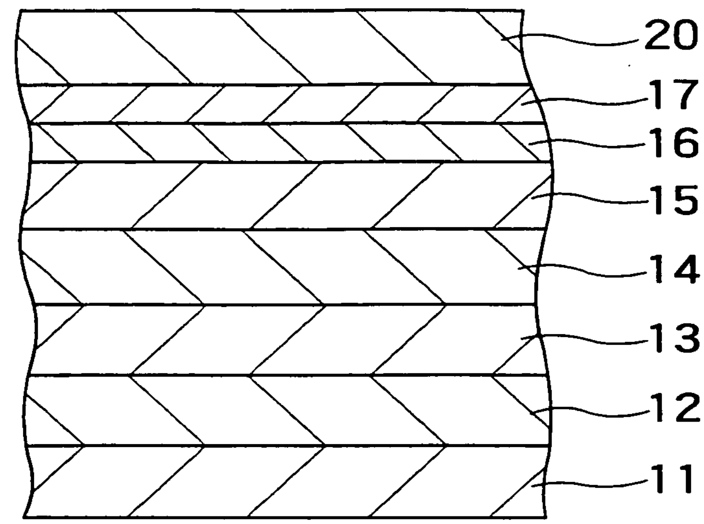


FIG. 18

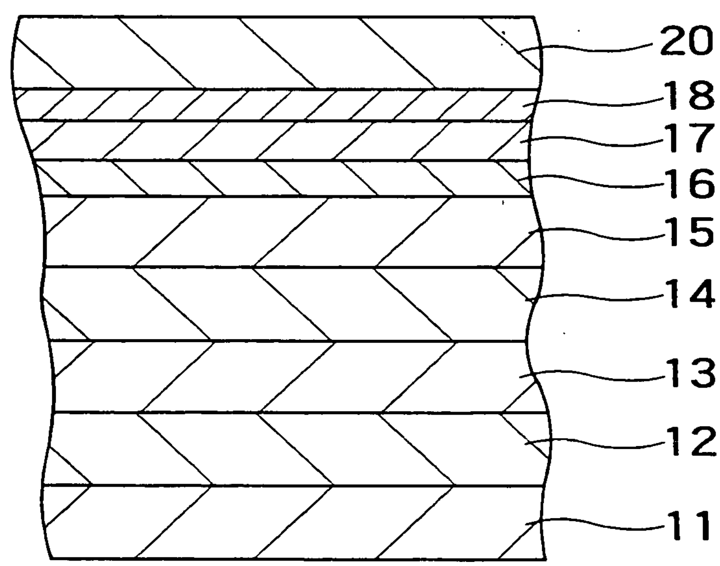


FIG. 19

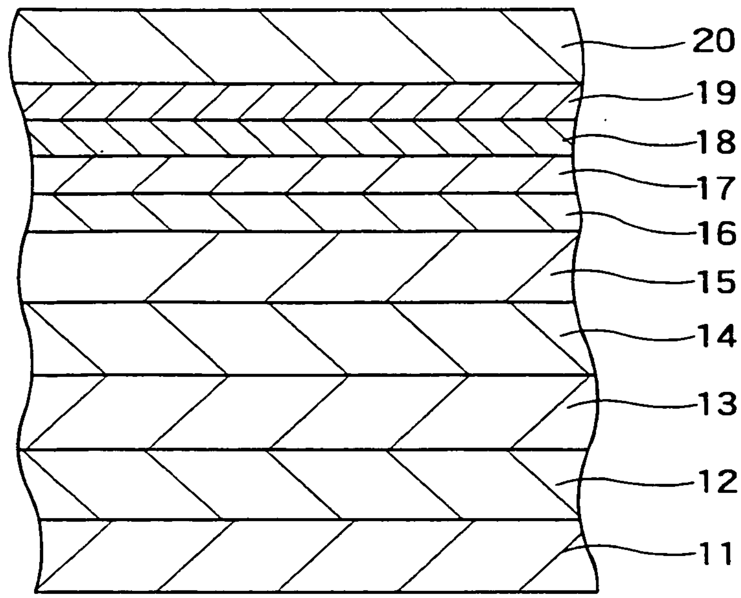


FIG. 20

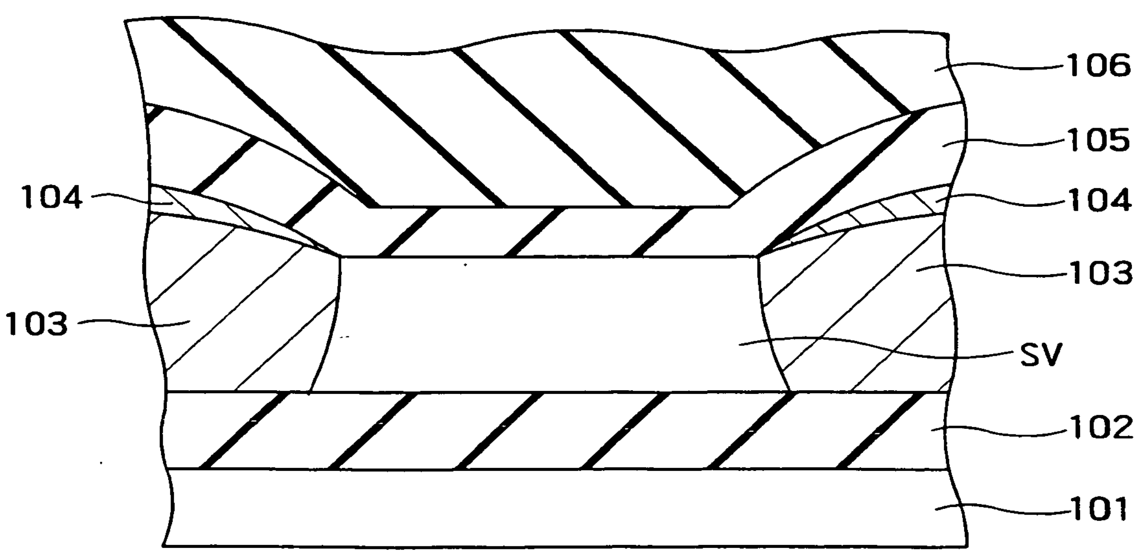


FIG. 21

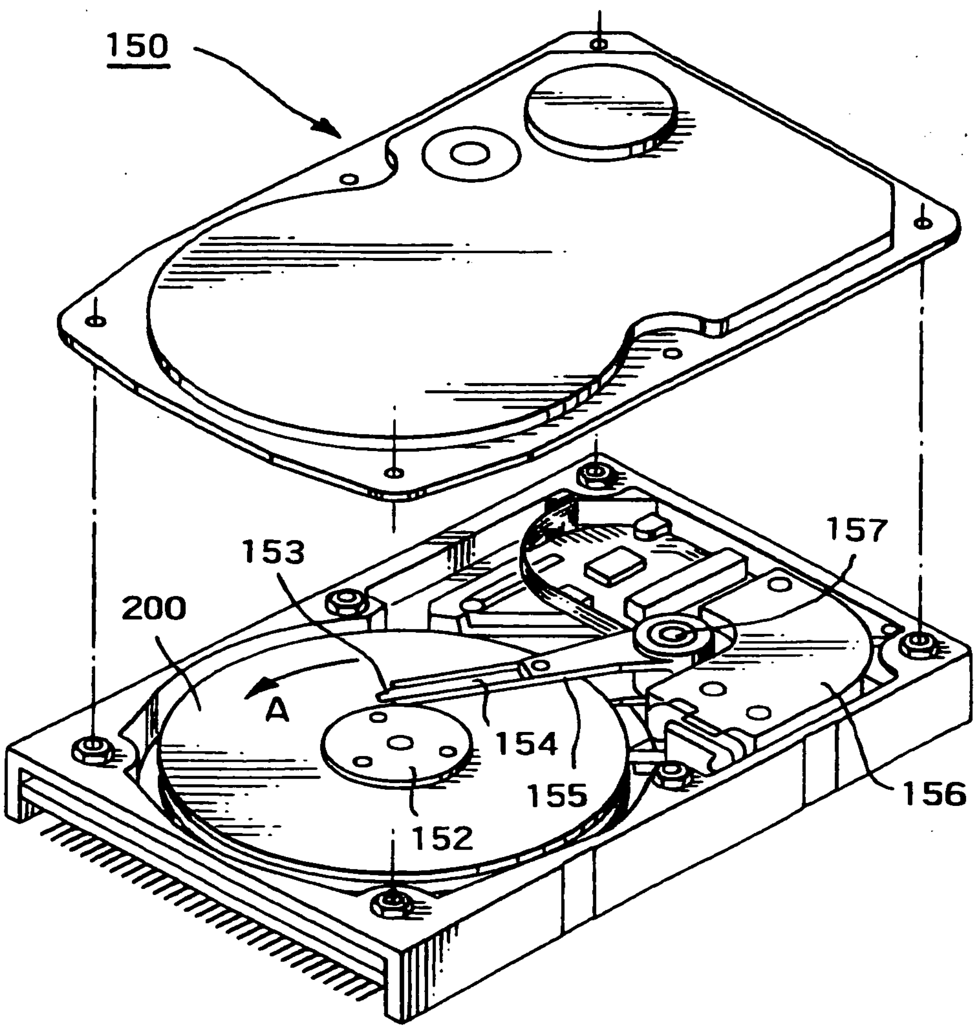


FIG. 22

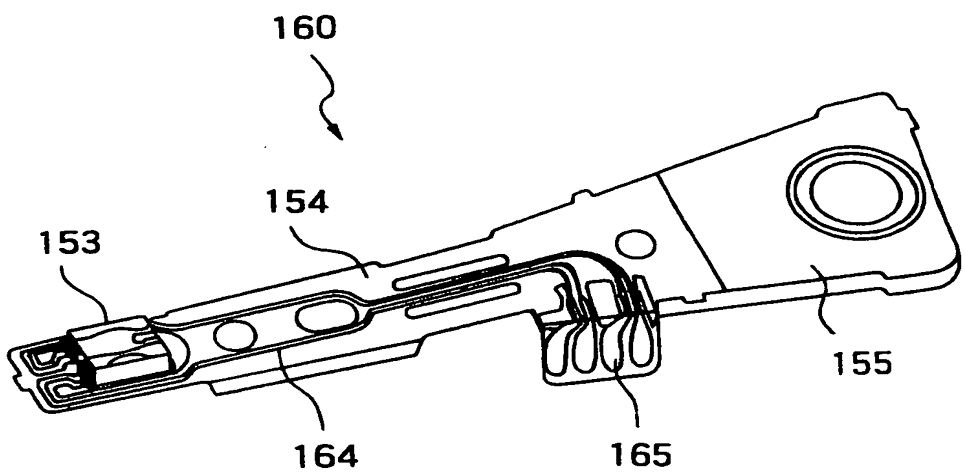


FIG. 23

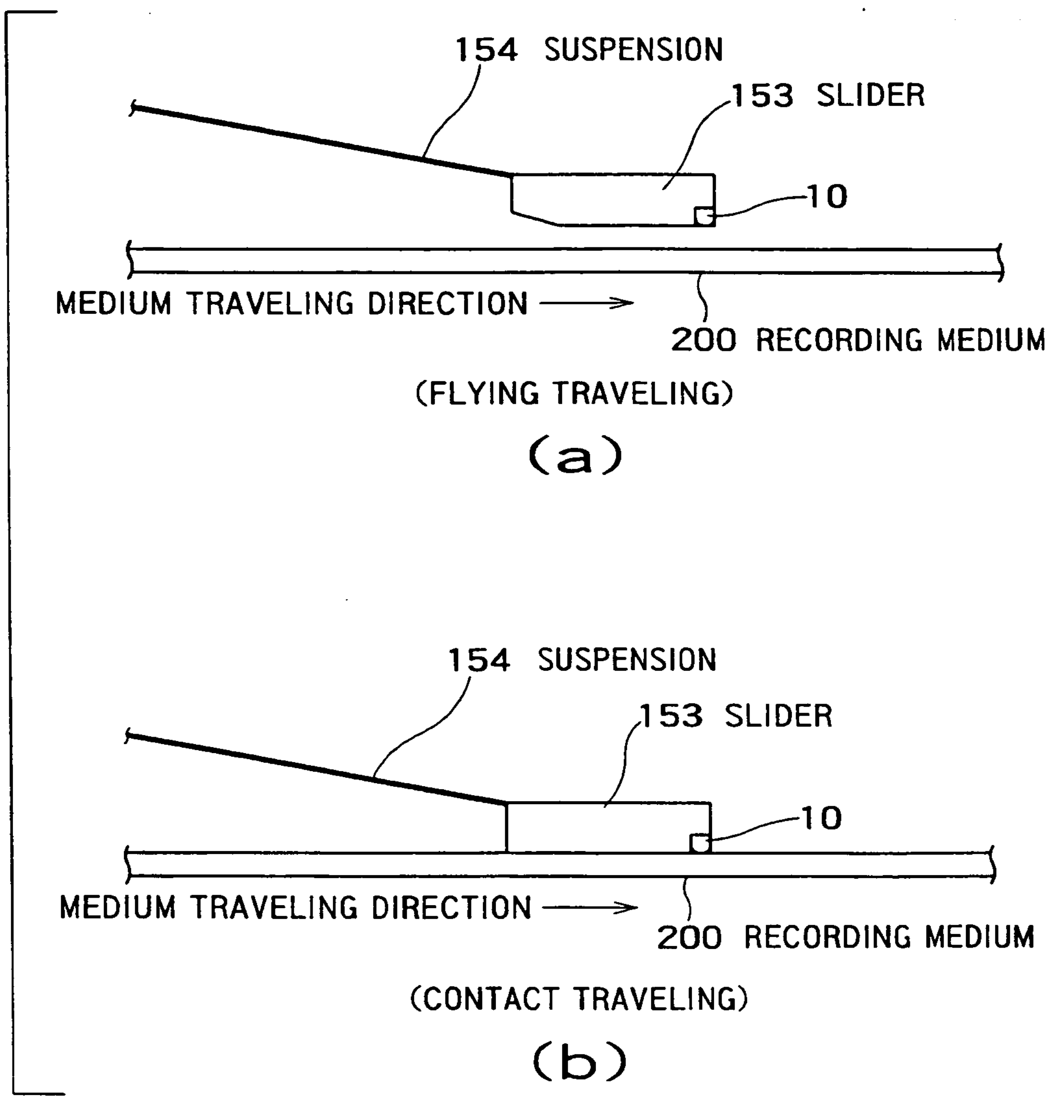

154 SUSPENSION
153 SLIDER
10
MEDIUM TRAVELING DIRECTION
200 RECORDING MEDIUM
(FLYING TRAVELING)
(a)
154 SUSPENSION
153 SLIDER
10
MEDIUM TRAVELING DIRECTION
200 RECORDING MEDIUM
(CONTACT TRAVELING)
(b)

FIG. 24